InLCA: Selected Papers

Integrating Life Cycle Cost Analysis and LCA

Gregory A. Norris

Sylvatica, 147 Bauneg Hill Road, Suite 200, North Berwick, Maine 03906 USA; e-mail: norris@sylvatica.com

Abstract. The private sector decision making situations which LCA addresses must *also* eventually take the *economic* consequences of alternative products or product designs into account. However, neither the internal nor external economic aspects of the decisions are within the scope of developed LCA methodology, nor are they properly addressed by existing LCA tools. This traditional separation of life cycle environmental assessment from economic analysis has limited the influence and relevance of LCA for decision-making, and left uncharacterized the important relationships and trade-offs between the economic and life cycle environmental performance of alternative product design decision scenarios. Still standard methods of LCA can and have been tightly, logically, and practically integrated with standard methods for cost accounting, life cycle cost analysis, and scenario-based economic risk modeling. The result is an ability to take both economic and environmental performance – and their tradeoff relationships – into account in product/process design decision making.

Keywords: Full cost accounting; InLCA; LCA for decision-making; Life Cycle Assessment (LCA); Life cycle cost analysis; total cost assessment; process design decision making; product design decision making

1 Introduction: Differences between LCA and Life Cycle Cost Analysis

The private sector decision making contexts addressed by LCA must also eventually take the economic consequences of alternative products or product designs into account. However, neither the internal nor external economic aspects of the decisions are within the scope of developed LCA methodology, nor are they properly addressed by traditional LCA tools. Neither has the ISO 14040 series of standards for LCA methodology addressed the integration of economic analysis with LCA.

Despite the similarity of their names, Life Cycle Cost analysis (LCC) and LCA have major methodological differences as summarized in Table 1. These differences stem from the fact that LCC and LCA are each designed to provide answers to very different questions. Life Cycle Assessment evaluates the relative environmental performance of alternative product systems for providing the same function. This environmental performance is assessed as holistically as possible, aiming to consider all important causally-connected processes, all important resource and consumption flows, regardless of whether or not they eventually impact anyone. Life Cycle Cost compares the cost-effectiveness of alternative investments or business decisions from the perspective of an economic decision maker such as a manufacturing firm or a consumer. These differences in their purpose have properly resulted in differences in their scope and method.

Let's consider the differences using the purchase of a computer as an example. First, note that the 'life cycles' being addressed by each method are different. The time horizon of an LCC analysis is the economic lifetime of the investment (Fuller and Petersen 1998, 1996). This economic lifetime can be even shorter than the 'usage phase' in LCA; it is set by the accounting conventions of the decision maker. For the LCC, the economic life of the computer might be three years, for example, after which point it is presumed to be sold at its 'salvage value'. For the LCA, the expected physical use life of the computer might be five years, or longer if repairs and upgrades are taken into account.

Table 1: How LCA and LCC differ in purpose and approach

Tool/Method	LCA	LCC
Purpose	Compare relative environmental performance of alternative product systems for meeting the same end-use function, from a broad, societal perspective	Determine cost-effectiveness of alternative investments and business decisions, from the perspective of an economic decision maker such as a manufacturing firm or a consumer
Activities which are considered part of the 'Life Cycle'	All processes causally connected to the physical life cycle of the product; including the entire pre-usage supply chain; use and the processes supplying use; end-of-life and the processes supplying end-of-life steps	Activities causing direct costs or benefits to the decision maker during the economic life of the investment, as a result of the investment
Flows considered	Pollutants, resources, and inter-process flows of materials and energy	Cost and benefit monetary flows directly impacting decision maker
Units for tracking flows	Primarily mass and energy; occasionally volume, other physical units	Monetary units (e.g., dollars, euro, etc.)
Time treatment and scope	The timing of processes and their release or consumption flows is traditionally ignored; impact assessment may address a fixed time window of impacts (e.g., 100-year time horizon for assessing global warming potentials) but future impacts are generally not discounted	Timing is critical. Present valuing (discounting) of costs and benefits. Specific time horizon scope is adopted, and any costs or benefits occurring outside that scope are ignored

The process scope of the LCC includes only those processes imposing direct economic costs (or benefits) upon the decision maker. Thus, we account for selling prices of inputs to the investment's economic life (for example, the purchase price of the computer, a pair of replacement batteries, and the electricity used during its life; we subtract the salvage value from the life cycle costs). As in an LCA, we might neglect costs which are expected to be equivalent among alternatives, which might include the costs of software, customer support, and electronic media.

For the LCA, we of course include all processes which are causally-affected by the life cycles of the alternatives, possibly neglecting those which are expected to be identical among alternatives. Thus, we include manufacture of the computer, manufacture of its components, provision of fuel and electricity to the entire supply chain, generating electricity to supply the use phase, recycling or landfilling of the computer after use, etc. The modeled processes may number into the hundreds in an LCA.

The two methods differ greatly in their flow scope. The LCC includes only the cost flows described above. Note that some of the cost flows may not be proportional to, or even dependent at all upon, physical flows modeled in the LCA. The LCC takes careful account of the timing of the cost flows, while LCA neglects flow timing. The LCC may also include cost *risks,* and how they are altered or avoided as a function of product/process design investment options. Finally, the LCA considers flows of pollutants and resources from each of the modeled processes.

As can be seen, properly and fully integrating meaningful economic analysis into LCA requires going well beyond simply treating economic cost as 'just another flow', or as another property of flows, within traditional LCA software. It requires the addition of a time dimension to the modeling; the ability to introduce and work with variables that have no causal dependence upon inventory flows; and the ability to create and work with probabilistic scenarios in order to capture risks.

The consequences of leaving LCC out of LCA were summarized in (Norris 2000). They are:

- Limited influence and relevance of LCA for decision making;
- Inability to capture relationships among environmental and cost consequences, which also inhibits the search for the most cost-effective means to environmental improvements;
- Potential to miss economically important or in some cases even economically pivotal environment-related consequences to the company of alternative decisions.

2 Two Approaches For Linking LCA and LCC

This section outlines two available approaches to fully integrating LCA with LCC. First it should be stressed that both approaches represent integrations of *full* LCA with *full* LCC. In the past proposals have been made which link either full LCA with partial LCC, or vice versa. The first class of partial solutions simply added cost flows into the traditional LCA framework, treating cost flows just like physical flows. This approach does not augment LCA with capabilities which are useful in an LCC sense, since it treats costs in ways which conflict with the key aspects of LCC listed in Table 1.

Another family of half-way approaches has added to LCC elements of 'streamlined' or truncated LCA, such as physical flows from the core company and perhaps some first tier suppliers. This approach lacks the LCA attributes listed in Table 1, and so fails to identify decisions which minimize total environmental burdens over the full life cycle.

2.1 Approach 1: PTLaser

A first combined solution, called 'PTLaser', begins with a capability for process modeling which satisfies and then goes beyond the required LCA attributes listed in Table 1. Non-traditional LCA process modeling capabilities present in PTLaser include the ability to define non-linear relationships anywhere in the system, to include non-flow-based causal influences among processes, to introduce scenarios and conduct multi-variate sensitivity analysis, and to define any parameter in the system as uncertain and then to conduct Monte Carlo uncertainty analysis.

To this suite of capabilities it adds the required LCC capabilities listed in Table 1. First, the dimension of time is present, which also enables dynamic LCA – e.g., time-varying input/output coefficients or emissions coefficients. Also provided is the ability to assign to any physical flow an unlimited number of different fixed and/or variable cost functions. Third, users can define investment costs and their timing for each alternative, and then employ flexible depreciation and tax accounting, as well as discounting (present valuing) of all costs and benefits. The analysis satisfies the activity scope requirements of LCC within an LCA-scoped model by allowing users to add only the costs borne by the decision-making firm.

PTLaser is also designed to provide robust treatment of two additional aspects not listed in Table 1 which are central to many LCCs of environmental investments: uncertainty and risk. Economic as well as physical parameters in the models can be defined as uncertain, even dynamically uncertain. The influence of all input uncertainties upon each alternative's results is then taken into account using Monte Carlo simulation, and uncertainties' influence can be compared as well. A scenario-building capability allows inclusion of occurrences which *may* take place with specified probability (allowed to be dynamic), and whose cost consequences can also be specified as dynamic and uncertain.

Based on the models user inputs, the program calculates life cycle inventories for the modeled system alternatives (LCA results) and provides financial evaluations of all alternatives (LCC results), present valuing costs and benefits. Further information about PTLaser is available at (Sylvatica 2000).

2.2 Approach 2: TCAce

A second tool has recently been completed by a collaborative effort of ten multinational companies and the American Institute of Chemical Engineers' Center for Waste Reduc-

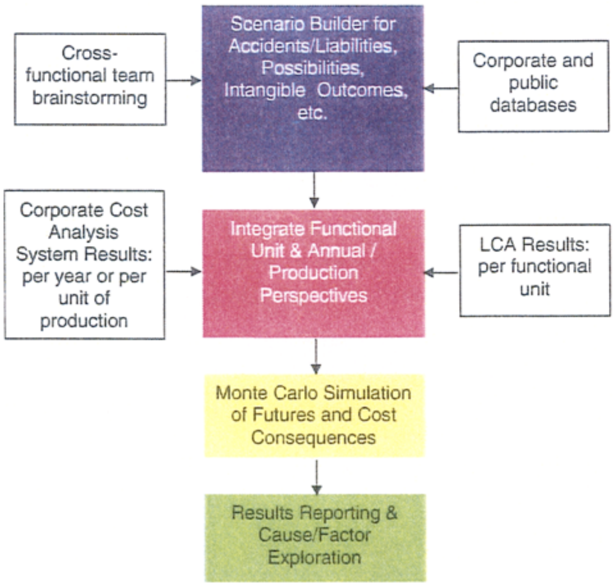

Fig. 1: Schematic of the TCAce Process

tion Technologies. The collaborative project developed a methodology for 'Total Cost Assessment' (CWRT 1999, Beaver 2000) (**Fig. 1**).

The methodology developed during the project differentiates five cost types as summarized in **Table 2**. Types 1 through 4 are internal costs borne by the company; these costs would be included in a comprehensive LCC evaluation of investment alternatives, although traditional LCCs typically capture only Type 1 (direct) and some Type 2 (indirect) costs. TCAce is specially designed to enable users to broaden the cost scope to include less tangible costs (types 4 and 5) applying quantitative methods which are fully consistent with their companies' existing approaches to LCCs of Type 1 and 2 costs. This consistency with existent corporate accounting conventions can include approaches to capital depreciation, treatment of taxes, discounting, and the time horizon of LCC evaluations. Also, users can import the results of conventional LCC of Type 1 and 2 costs into TCAce from their existing financial accounting software or databases.

TCAce also allows users the option of estimating 'external' Type 5 costs – those borne by parties other than the decision making company or its suppliers or customers. Type 5 costs can depend in part upon the Life Cycle Inventory data imported by the user into TCAce from their standard LCA software. If they are included in the analysis, Type 5 costs must still be kept separate from internal costs, since they do not directly impact the cost-effectiveness of a decision. For example, in its application of TCAce, the Dow Chemical Company addresses true business costs only, Types I through IV, in their current decision making process. They still look at Type V costs – but primarily from a public policy perspective and as one tool to influence appropriate public policy.

TCAce is already helping the collaborating CWRT companies to re-evaluate (and in reported cases, *change for the better*) millions of dollars' worth of decisions, both capital investment as well as product-related. It does this by expanding the decision scope to include conventionally-overlooked factors which may be important. As the leading TCAce user in one company reported, "we always knew those costs were out there, but we had no way of dealing with them on the same basis as our Type 1 and 2 costs."

One of the key ways TCAce users are achieving these outcomes is by using the software as a mechanism for integrating judgments and information from across the company. The TCAce scenario-builder can be used during interactive workshops which facilitate and integrate inputs and ideas from company-wide cross-functional teams of experts. These workshops have been reported to stimulate thinking and yield insights which would not have been generated by company individuals working in isolation. The dynamic cost and benefit consequences of these insights are then integrated with conventional analyses, broadening decision makers' perspectives and ultimately leading to better decisions.

References

Beaver E (2000): LCA and Total Cost Assessment. Environmental Progress 19 (2) 130-139

CWRT 1999: Total Cost Assessment Methodology. Center for Waste Reduction Technologies, American Institute of Chemical Engineers, New York, NY. (see also: www.aiche.org/cwrt/projects/cost.htm)

Fuller S, Petersen S (1996): Life Cycle Costing Manual for the Federal Energy Management Program. Gaithersburg, MD: National Institute of Standards and Technology. (Detailed guidance for Life Cycle Cost analysis, with application to the evaluation of energy conservation investments.) Available at: http://www.bfrl.nist.gov/oae/publications/handbooks/135.html

Fuller S, Petersen S (1998): Life Cycle Costing Workshop for Energy Conservation in Buildings: Student Manual. Gaithersburg, MD: National Institute of Standards and Technology. Available at: http://www.bfrl.nist.gov/oae/publications/nistirs/5165.html

Norris GA (2000): Integrating Economic Analysis into LCA. Environmental Quality Management 10 (3) 59-64

Sylvatica (2000): PTLaser, information and user's guide downloadable from http://www.sylvatica.com/tools/htm

Table 2: Cost types in the AIChE/CWRT total cost assessment method and TCAce

Cost Type	Description
Type 1: Direct	Direct costs of capital investment, labor, raw material and waste disposal. May include both recurring and non-recurring costs. Includes both capital and O&M costs
Type 2: Indirect	Indirect costs not allocated to the product or process (overhead). May include both recurring and non-recurring costs. Includes both capital and O&M costs
Type 3: Contingent	Contingent costs such as fines and penalties, costs of forced clean-up, personal injury liabilities, and property damage liabilities
Type 4: Intangible	Difficult to measure costs, including consumer acceptance, customer loyalty, worker morale, union relations, worker wellness, corporate image, community relations
Type 5: External	Costs borne by parties other than the company (e.g., society)